Research on Improving Measuring Accuracy of Crude Oil Water Content Sensor

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Abstract

Water content is an important technical index in crude oil detection. There are many multiphase interfaces in the process of measuring water content of crude oil by contact sensor. In this paper, the contact time between the sensor and crude oil, the rate of crude oil flowing through the probe and Langmuir temperature adsorption model were used to study the adsorption characteristics under different conditions. The characteristic adsorption curve was obtained. Experiments show that the main factor affecting the measurement accuracy of water content sensor is temperature. Therefore, according to the influence trend of temperature, calibration of sensor can effectively reduce the measurement error of sensor and improve the measurement accuracy of crude oil water content sensor.

Keywords

Water content of crude oil, multiphase interface, adsorption characteristics, measurement accuracy.

1. Introduction

In the petrochemical industry, the water content of crude oil is one of the main measurement parameters in the process of crude oil production and processing.The accuracy and timeliness of water cut data measurement are of great significance to crude oil production and management decision-making.

At present, there are many methods to measure the water content of crude oil, such as traditional time sampling distillation method, ray method, microwave method[1], capacitance-phase angle conversion method[2], non-contact all-optical measurement method[3], etc. When measuring the water content of crude oil, the electromagnetic conductivity sensor[4] part contacts with the fluid for a long time. The crude oil will form an adsorption layer on the surface of the probe. When the water content of crude oil changes, the sensor can't accurately sense the change of water content, which can lead to the failure of the measuring device. It is necessary to explore the influence of various factors on the adsorption behavior among the three factors. And the research results are applied to the on-line water content detection device, which can improve the reliability and accuracy of the measurement.

2. Adsorption Mechanism

When the probe with polytetrafluoroethylene (PTFE) coating on the surface contacts with crude oil, an interfacial layer will be formed. The molecules on the interface layer are PTFE and crude oil respectively. The properties of PTFE and crude oil are quite different, and the force is not uniform, so there is interfacial energy. The lower the interfacial free energy is, the more stable the system will be, so the material always tends to minimize the interfacial energy. The trend is that the interface area decreases or the adjacent material molecules are adsorbed to achieve [5]. The PTFE is the main component of the coating on the probe surface. Solid molecules can't move freely on the surface, and the interface area is not easy to reduce. Therefore, surface energy can only be reduced by adsorbing crude oil molecules in contact with it.

3. Design and analysis of experimental research

The coated probe is placed upright in a beaker filled with water. One end of the capacitance meter is vertically inserted into the water. The other end is connected with a stainless steel wire without coating at the tip of the probe. According to the principle of capacitance formation, the reading of capacitance measuring instrument is the capacitance value formed by the probe part with coating immersed in water. The sensitivity coefficient K is the output capacitance of the probe coating immersed in water per millimeter in this experiment.

The medium with different oil-water volume ratio is mixed to simulate the process of oil-water mixture passing through the probe surface at a certain speed in the actual oil pipeline. The experimental method is to mix oil-water mixtures with different volume ratios uniformly under the action of a magnetic stirrer. The oil-water mixture is then heated to a specified temperature. At a certain speed, the probe is immersed in the oil-water mixture. Finally, the distribution of oil film on the probe surface and the relationship between the water film height and the output capacitance were observed. The purpose of heating is to equivalently heat the probe surface with a heating wire. Because the heating wire still has heating effect on the crude oil adsorbed on the probe surface in the actual measurement process, it is necessary to consider the influence of different crude oil temperature.

3.1 Analysis for the influence of contact time

The relationship between the contact time of the probe and the oil-water mixture and the amount of crude oil adsorbed on the surface of the probe is shown in Fig. 1.

At the same moisture content, the adsorption capacity decreases with the increase of temperature.It can be seen from the figure that when the water content is 90%, 80% and 70%, the adsorption capacity at 44 ℃ is obviously less than that at 42 ℃. For liquid phase, when temperature rises, crude oil molecules move more intensely, increase the distance between molecules, reduce the interaction force between molecules, and decrease the viscosity of crude oil, which results in the decrease of the adsorption amount of crude oil molecules on the surface of the probe.

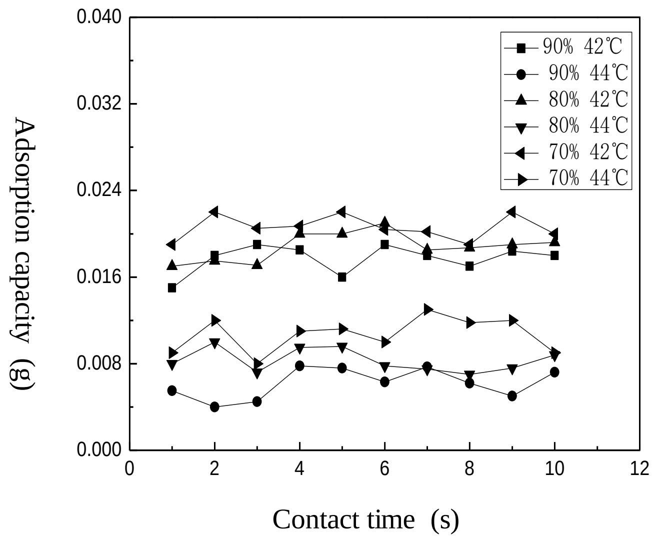

Fig. 1 Curve of the relationship between contact time and crude oil adsorption

At the same temperature, the adsorption capacity of the probe with high moisture content is slightly less than that of the probe with low moisture content. It can also be seen from the graph that at the same temperature, the adsorption capacity of the probe with high moisture content is slightly smaller than that of the probe with low moisture content. When the temperature is 44 ℃ and the water content is 90%, the adsorption of oil-water mixture on the probe surface fluctuates around 0.006g. When the moisture content is 70%, the adsorption capacity fluctuates around 0.01g.This is because at the same temperature, when the water content is high, the concentration of crude oil in the oil-water mixture is low, which makes the overall viscosity of the oil-water mixture low, and leads to a slight decrease in the adsorption capacity of the oil-water mixture on the surface of the probe.

3.2 Analysis for the influence of stirring speed

The relationship between the stirring speed of the magnetic stirrer for oil-water mixture and the adsorption capacity of crude oil is shown in Fig. 2.

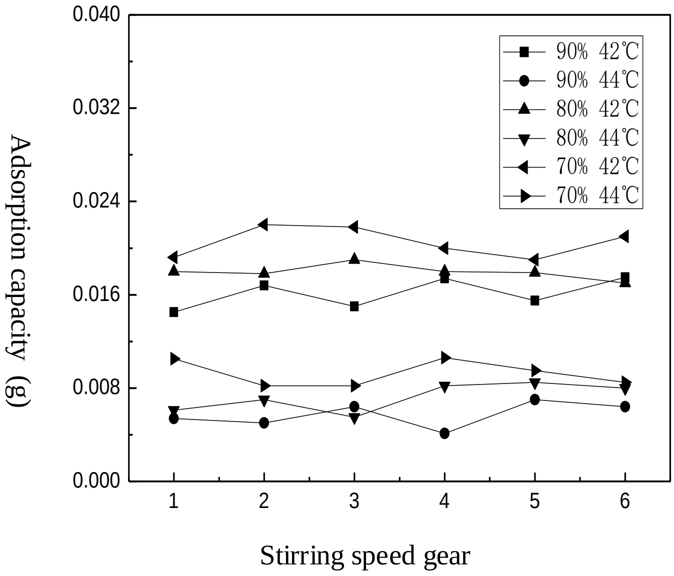

Fig. 2 Curve of relationship between stirring speed and crude oil adsorption capacity

It can also be seen from the figure that when the temperature changes, the adsorption amount of oil-water mixture with different water content will change obviously. The higher the temperature, the smaller the adsorption capacity. No matter from the data comparison, or from the change trend comparison, and the change rule of Fig.1 tend to be consistent. It is noteworthy that the effect of temperature on the adsorption capacity is much greater than that caused by the change of concentration. At the same temperature, the increase of concentration will lead to the increase of adsorption capacity.At the same concentration, the adsorption capacity decreases with the increase of temperature.For oil-water mixtures with 90% water content, the adsorption capacity will decrease from 0.016g to 0.005g when the temperature increases from 42℃ to 44 ℃.

The change range of adsorption capacity was 0.011g when the temperature changed to 2℃. When the temperature is 44℃, the water content of crude oil decreases from 90% to 70%, the adsorption capacity will change by 0.003g. This shows that the change of temperature on adsorption is much greater than that caused by concentration and stirring speed. Temperature is the most important factor for the change of crude oil viscosity.

3.3 Isothermal adsorption curve analysis

Using Langmuir isothermal adsorption model [6], an isothermal adsorption line with Concentration (g/mL) as the transverse axis and Concentration/Adsorption capacity(1/mL) as the longitudinal axis is obtained as shown in Fig. 3.

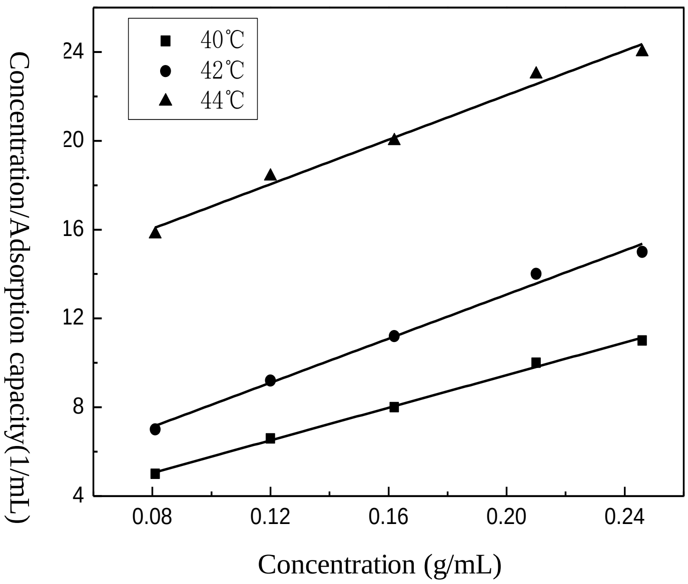

Fig. 3 Langmuir Isothermal Adsorption Line at Different Temperatures

From the Fig.3, we can see that at different temperatures, the boundary between straight lines is obvious, and the position of straight lines has certain regularity.When the temperature is 40°C, for the same concentration, the value of ordinate is inversely proportional to the amount of adsorption, so the straight line is at the lowest end.When the temperature is 44°C, the crude oil viscosity decreases, so the crude oil adsorption on the probe surface decreases. For the same concentration, the longitudinal coordinate value is inversely proportional to the adsorption amount, so the straight line is at the top.

Table 1 Error comparison of field experiment data

Sampling time	Detection value（%）	Sampling value (%)	Relative error（%）
8:45	76.40	70.09	5.90
9:30	77.27	79.45	-2.74
10:25	81.53	76.05	7.02
11:15	83.13	78.00	6.75
13:30	73.62	68.31	8.07
14:30	71.16	70.24	1.31
15:10	72.60	76.40	-4.97
16:00	69.62	72.37	-3.80
9:15	79.54	83.39	-4.61
10:00	79.43	84.09	-5.54
10:45	76.29	78.92	-3.31
12:30	76.35	81.56	-6.39

4. Conclusion

Stirring speed and contact time have no effect on crude oil adsorption on the probe surface at the same moisture content and temperature. At different temperatures, the adsorption capacity of the probe surface is different, and the moisture content corresponds to the temperature one by one. According to Langmuir isothermal adsorption curve, the adsorption capacity of crude oil on the probe surface corresponds to temperature at the same water content. Calibrating the adsorption capacity of crude oil at each temperature and water content can determine the corresponding capacitance output value and improve the measurement accuracy of the sensor. Field application results show that the accuracy of water content sensor measurement after calibration is improved to within (±8%). The error comparison of field experimental data is shown in Table 1.

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